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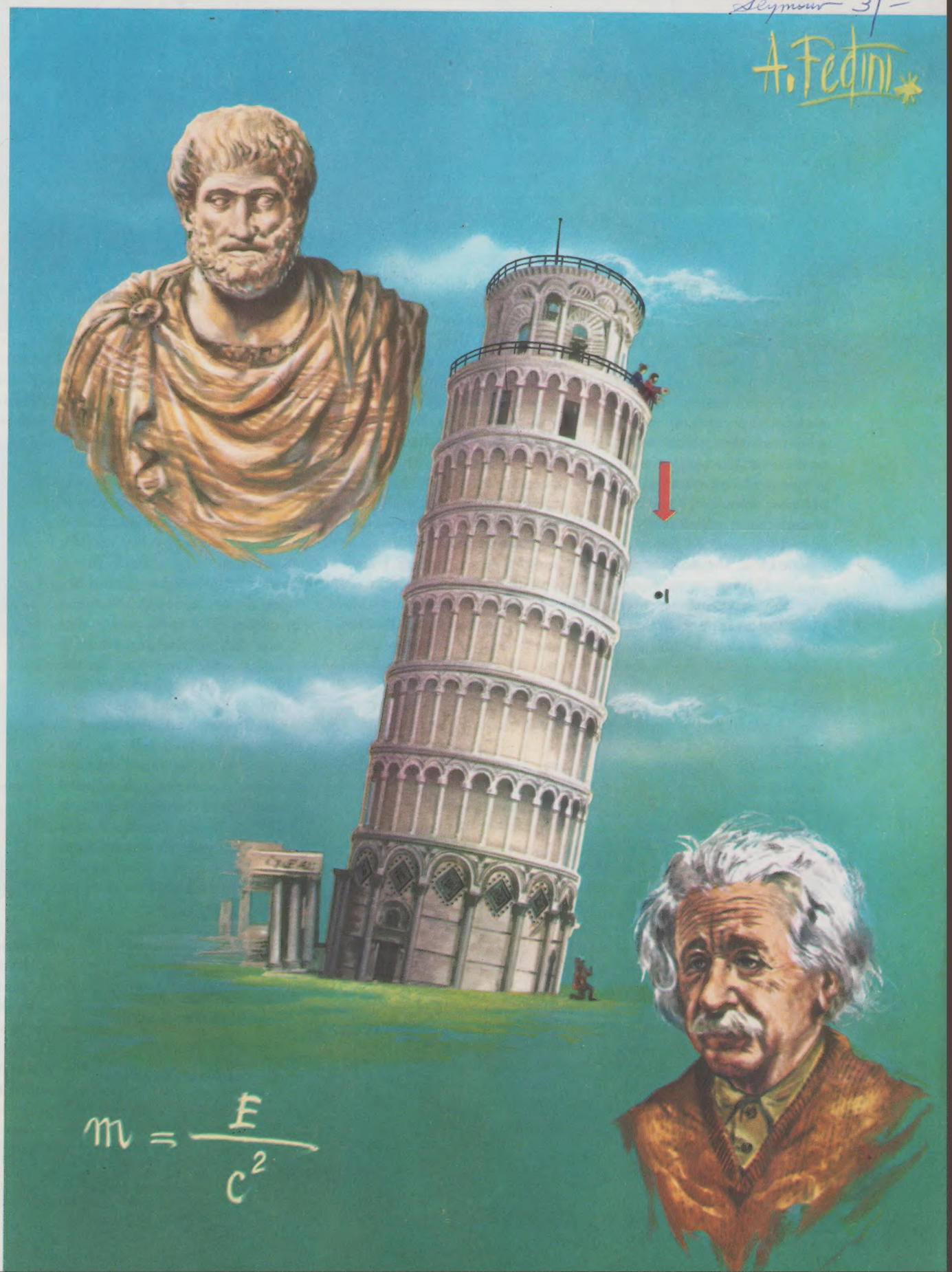

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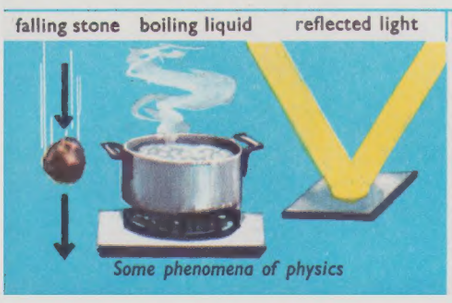
PHYSICS

THE words 'physics' and 'physicist' are being used more and more in a world which spends millions of pounds each year on scientific research. We usually hear them in connection with atomic and nuclear physics, but this may give a wrong impression of the meaning and purpose of physics. Physics covers much more than these two fields of research.

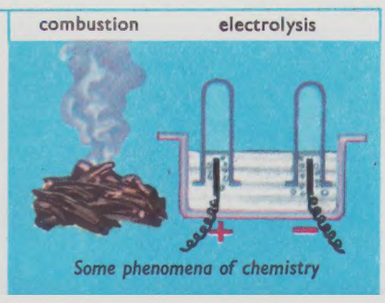
Like all other sciences, physics began because certain men in each generation have always been curious about things around them. What, they wondered, causes thunder and lightning? What are stars and planets? Why does a stone fall down to the earth and not up to the sky, and why does wood float and yet stone sink? How can birds fly but not man? Many people in past centuries (and indeed today) were willing to accept these events without curiosity and to believe unsatisfactory and perhaps supernatural explanations without question. But others, whom we now call scientists, have kept up an endless search to discover the mysteries of our world.

Science has become divided up into many branches, including physics, chemistry, mathematics, biology, and geology. Physics is the science which deals with the properties of and happenings in nature, such as light, sound, heat, motion, electricity, magnetism, and the properties of atoms right down to their tiniest parts. Physics, more than any other, is a precise science. It uses its 'sister' science mathematics as much as possible to explain the events occurring in nature. A physicist must be able to express what he measures in an exact way, so that any other physicist, no matter where he may be, will be able to repeat the experiment and check the results. It is useless to say that the light from a star is as bright as the fairy lights on a Christmas tree. A physicist will compare the brightness of the star with a standard source of light, and express the brightness as an exact mathematical fraction of that standard. It is only by taking precise measurements of natural happenings over long periods of time that the basic simplicity of nature has been discovered.

Physics is closely related to chemistry, and it is necessary to draw a distinction between the two. Chemists study materials to discover the type of atoms of which they are made. They are interested in the reactions occurring when two or more substances are brought together under various conditions of temperature and pressure. They are mainly concerned with transforming one substance into another. Physicists study the properties of materials: their strength, hardness, and structure; they also study light, heat, gravity, motion, electricity, and similar phenomena which are generated in, absorbed by, or in any way influence these materials without changing them into entirely different materials.

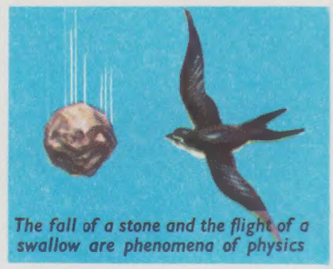


Some phenomena of physics



Some phenomena of chemistry

Some physical phenomena which do not change substances into others are: the effect of gravity on a falling stone, the boiling of a liquid, and the reflection of light. Two chemical phenomena in which substances are transformed into others of different composition are: combustion (burning wood transforms complex organic molecules into CO_2 and other gases), and electrolysis (splitting water into hydrogen and oxygen).

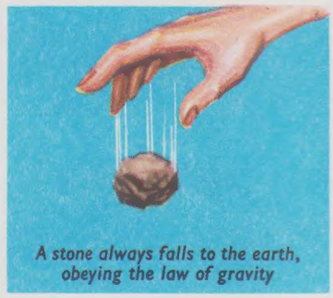

The fall of a stone and the flight of a swallow are phenomena of physics

Phenomena, theories, laws

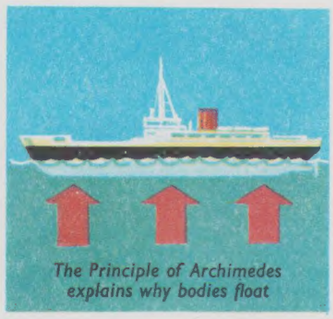
We should now define four important words. These are phenomena, theories, and laws (or principles).

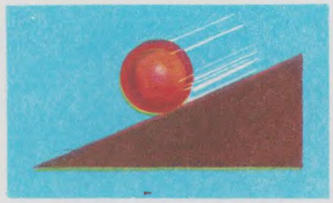
Phenomenon. In everyday speech the word 'phenomenon' means something astonishing and inexplicable; but in physics a phenomenon is almost anything which occurs in nature – the fall of a stone, the flight of a bird, a clap of thunder.

Theory. This is an idea which a scientist has, which may explain his observations of a particular phenomenon of nature. If the theory is tested and found to be correct, a new law may be discovered.


A stone always falls to the earth, obeying the law of gravity

Laws and principles. These are rules governing all phenomena in nature. If a stone is dropped it will fall to the ground at a definite rate, according to the law of gravity; no matter how many times this happens the law is still obeyed. Archimedes' Principle (or law) tells us that when a body is immersed in a fluid it will experience an upward thrust equal to the weight of fluid it displaces. This law, too, is always obeyed. Laws are ways of describing the workings of nature in as simple a way as possible.


The Principle of Archimedes explains why bodies float


A phenomenon of classical physics

Classical physics and nuclear physics

In recent years physics has become divided up into two parts: classical physics and nuclear physics. Classical physics explains the properties of objects which are large compared to an atom – objects which are visible

Previous page: (top left) a bust of Aristotle, philosopher and scientist; (centre) Galileo on the leaning tower of Pisa conducting his experiment on the free fall of a body; (bottom right) Albert Einstein, the greatest physicist of our time; (bottom left) Einstein's formula expressing the possibility of changing mass into energy and *vice versa*.

The advent of air transport has enabled Brazilians to open up and develop the vast interior of their country

BRAZIL: economy

BRAZIL is an enormous country, the fifth largest in the world after the USSR, Canada, China, and the United States. The whole country is dominated by the rolling hills and mountains of the Brazilian Highlands (although no peak reaches more than 10,000 feet), and great areas, particularly around the Amazon basin, are covered by vast tropical forests (see page 2756). Brazil's population is only one-sixth the size of India's, although her area is 2 million square miles larger.

In many ways the economy of Brazil is typically South American. Wealth is found side by side with poverty; great strides in industrial development in recent years are masked by overwhelming backwardness in most sectors of the economy; a high proportion of the growing population is illiterate; most Brazilians are employed in agriculture rather than industry; and the whole economy is largely dependent on a single product – coffee.

This dependence on one main export is characteristic of many Latin American countries. A country like the United Kingdom exports a vast range of products to all parts of the world. But in Latin America, Venezuela, for example, relies mainly on oil, and Cuba on sugar. Other examples are: Bolivia, whose exports consist almost entirely of minerals; and Chile, whose major product is copper. Ecuador, Honduras, and Panama all concentrate on producing bananas, and several countries rely almost entirely on coffee to earn money from foreign countries. These include Colombia, El Salvador, and Brazil. Nearly one-quarter of all South America's exports consists of coffee, and Brazil is far and away the most important producer. Indeed, almost two-thirds of all Brazil's exports are of coffee.

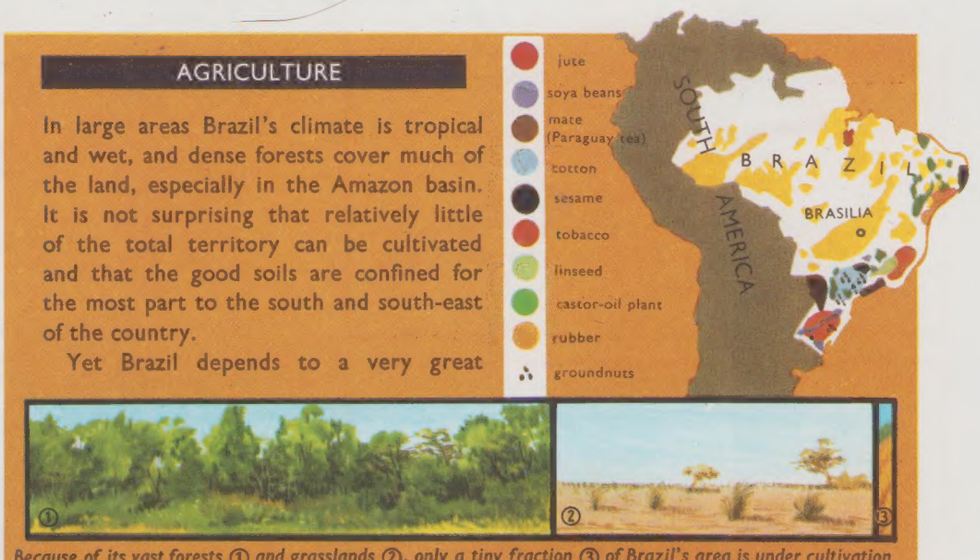
Oil, tin, coffee, bananas, copper – all are primary products, dependent on mining and agriculture. Concentration on primary products is another characteristic of South American countries, and results in the slow development of the manufacturing industries which are so essential to the expansion of their economies and the progress of their peoples.

The dangers in concentrating on a single primary product are well illustrated by the present difficulties of the Brazilian economy. With coffee prices tending to fall, Brazil finds it difficult to export enough to pay for the imports such as petroleum, machinery, and chemicals which she needs to industrialise and produce different products, and to raise the standard of living of the people, most of whom are miserably poor.

AGRICULTURE

In large areas Brazil's climate is tropical and wet, and dense forests cover much of the land, especially in the Amazon basin. It is not surprising that relatively little of the total territory can be cultivated and that the good soils are confined for the most part to the south and south-east of the country.

Yet Brazil depends to a very great extent on her agriculture, and agricultural products form the bulk of her exports. Brazil is the world's leading producer of livestock, coffee, and castor beans. She is the second largest producer of oranges, and third in the production of cocoa beans and sugar. Her tobacco production ranks fourth in the world, after the United States, Communist China, and India.



Because of its vast forests ① and grasslands ②, only a tiny fraction ③ of Brazil's area is under cultivation

BRASILIA

On 21st April 1960 a new modern capital was opened in the previously almost uninhabited Central West region of Brazil. It was named Brasilia, and given the status of a Federal District. Brasilia is a symbol of the Brazilians' resolve to develop the vast unexploited interior of their country.

NORTH BRAZIL

This vast tropical zone, with much of its jungle still unexplored, is covered by forests. Virtually uninhabited, the region's contribution to Brazil's economy comes mainly from tropical fruits and hardwoods.

EAST BRAZIL

Rio de Janeiro, the second largest city of Brazil, belongs to this region, and much of Brazil's industry is concentrated here. Agricultural products include cereals, coffee, cocoa beans, and tobacco.

NORTH-EAST BRAZIL

The main products of this agricultural region are cane sugar and tobacco. Bahia state produces 90 per cent of Brazil's cocoa.

SOUTH BRAZIL

This area is the richest and most populous in Brazil, and includes the country's most rapidly developing industrial state, São Paulo. The vast cattle farms of the Rio Grande also make it an important area for livestock production.

CENTRAL WEST BRAZIL

This region is being rapidly opened up, and Brazil's new capital, Brasilia, was inaugurated here in April 1960. The main products are cereals and livestock.

Ships being loaded in the main 'coffee port' of Santos

A fine herd of beef cattle on a ranch in southern Brazil

MAIN AGRICULTURAL PRODUCTS

Coffee: this product, the basis of the entire economy, is produced in several areas. São Paulo is one of the main producers, and much of Brazil's coffee is exported through her great port, Santos.

Cotton: cotton is produced in great quantities in North and South Brazil, and used to form Brazil's second largest export.

Cocoa: cocoa beans now rank second to coffee in Brazil's exports, and Brazil is the world's largest producer.

OTHER PRODUCTS

Brazil produces a great variety of other agricultural products, including tobacco, rice, maize, cane sugar, and rubber. Of less importance, but also produced in large quantities, are various fruits (including bananas, pineapples, and citrus fruits), wheat, and potatoes.

The tropical forests yield great quantities of timber, and pinewood is a major export. It is said that in the Brazilian selva (tropical rain forest) there are as many as 3,000 different species of trees to the square mile, and Brazil owns 5,500 of South America's 8,000 sawmills.

LIVESTOCK

Brazil is the greatest producer of livestock in the world, and two-thirds of the cattle are contained in the big ranches of the Rio Grande in the south. Much of the remainder is found in the states of São Paulo and Minas Gerais.

The numbers of livestock in 1960 were:

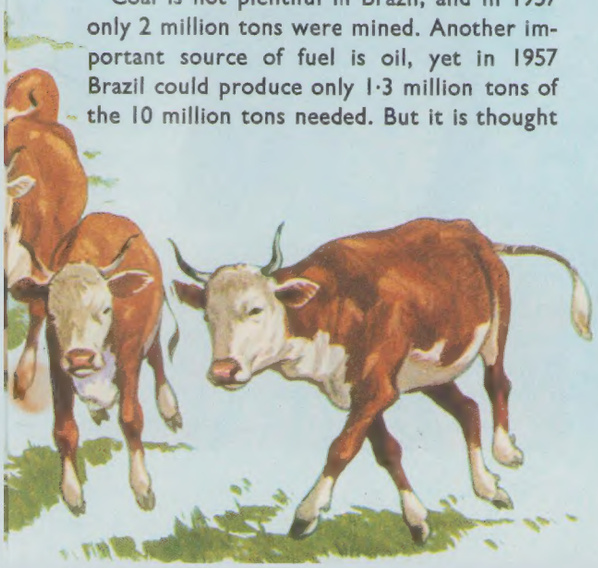
cattle	73,962,000
pigs	47,944,000
sheep	18,162,000
goats	11,195,000

MINERAL RESOURCES

Untapped mineral wealth is one of the keys to Brazil's economic future. The state of Minas Gerais is rich in minerals, above all in iron ore. Brazil has some of the largest iron deposits in the world, and there is at present a great increase in production, not only in Minas Gerais, but also in the Mato Grosso.

Coal is not plentiful in Brazil, and in 1957 only 2 million tons were mined. Another important source of fuel is oil, yet in 1957 Brazil could produce only 1·3 million tons of the 10 million tons needed. But it is thought that Brazil may contain large oilfields, and may one day become a leading producer.

Other minerals, some of them very rare, exist in various parts of the country. Brazil produces almost the entire world output of quartz crystals. And bauxite, manganese, industrial diamonds, chrome ore, zirconium, mica, beryllium, nickel, tungsten, lead, graphite, and gold are all mined to some extent.



THE FUTURE

In years to come Brazil may well become the leading industrial country of South America. She has vast areas of uninhabited land and huge mineral resources. The population is growing rapidly, but at present 40 per cent is under 15 years of age, and half the population is illiterate. This raises enormous problems of education, and means that children start work in Brazil at an early age.

Brazil will have to become less dependent on coffee, and develop manufacturing industries. Already great progress is taking place, and industrialisation has been particularly rapid since 1955. In 1950 wood provided the major source of fuel, but now its place has been taken by petroleum and hydro-electric power. There has been a great development of hydroelectric power recently, and Brazil is the largest producer in South America.

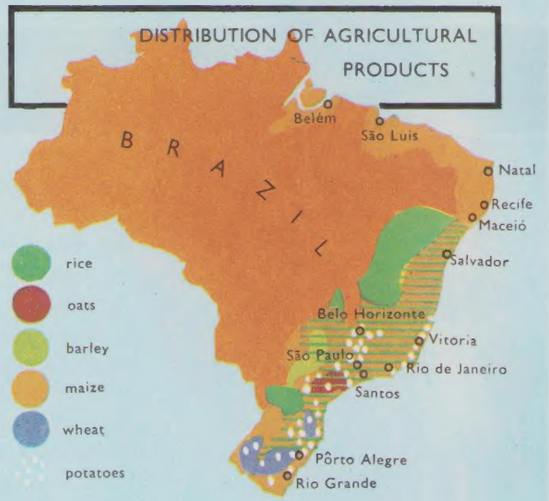
The government plays a major role in the Brazilian economy. It operates certain mines, controls the petroleum industry, and owns the biggest steel mill in the country. It owns most of the railways and the merchant navy, and in many other respects, too, the government's position is such that it will continue to play a large part in shaping the future of Brazil's economy.

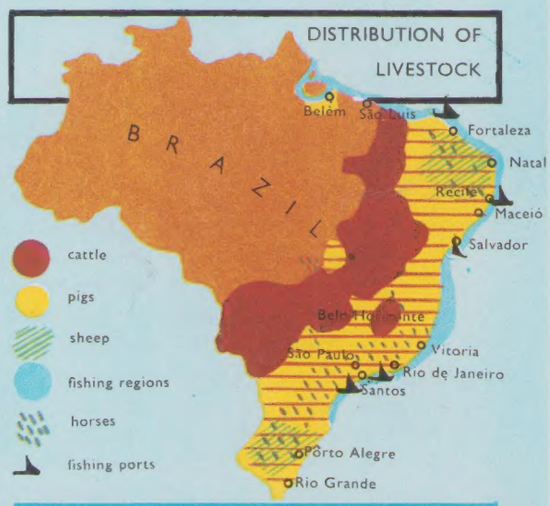
COMMUNICATIONS

The transport network is as yet inadequate for the needs of such a huge territory. The only areas where the railway network is fairly dense are in the states of São Paulo and Minas Gerais. Brazil is crossed by great rivers, especially the Amazon and its tributaries, but these are not of great value for inland transport as they do not serve the main areas of mineral resources, the best agricultural regions, and the great cities and ports. As a result, air transport is becoming increasingly important as a means of overcoming the problems created by Brazil's vast distances.

DEVELOPING INDUSTRY

Industry is fast developing. Cotton weaving is the major industry, concentrated in São Paulo, and employing one-quarter of all industrial workers. But other industries, such as cars, machinery, and chemicals, are developing, and it seems certain that the future of Brazil's economy lies in growing industrialisation.





FACTS AND FIGURES

Population (1960): 70,967,185

Largest towns:

São Paulo	3,825,351
Rio de Janeiro	3,307,163

Main ports: Rio de Janeiro; Santos; Recife

Railway mileage: 23,000

Main exports: coffee, cotton, cocoa beans, rice, fruit

Main imports: Petroleum, machinery and metal goods, chemicals, wheat

EUROPE IN THE 15th

A 15th-century nobleman

WHEN did the Middle Ages end and modern history begin? Some say in 1453 when Constantinople fell to the Turks and Byzantine scholars fled to western Europe, bringing with them the New Learning. Others say 1485 when the Yorkists were replaced by the Tudors in England. There are some who place the date at 1492 when Columbus widened the world by discovering America, while others think modern history began with the era of the Italian wars started by Charles VIII in 1494.

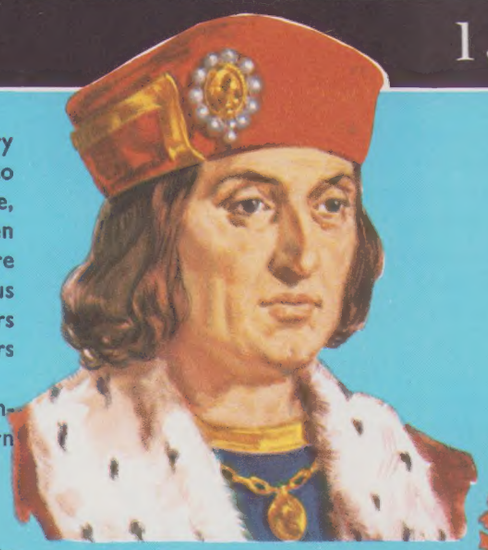
You will notice that all these dates are in the 15th century – a century clearly decisive in the evolution of modern Europe.

The Papacy and the 'conciliar' movement

But, in at least one respect, the 15th century turned its back on a 'progressive' movement. For in this century the so-called 'conciliar' movement tried to limit the authority of the Pope, stressing instead that of the General Councils of the Church. The movement failed, and at the end of the 15th century the Pope was the almost unchallenged ruler of the Catholic Church.

When the century opened, the Great Schism was in progress. The two rival Popes hurled defiance and insults at each other. The Pope acknowledged by England, the Roman Pope Urban VI, was succeeded by Boniface IX, Innocent VII, and, in 1406, Gregory XII. The French 'Pope' 'Clement VII' was succeeded by 'Benedict XIII'. How could this difficulty be resolved? The growing feeling among the cardinals was that only a General Council of the whole Church could decide, and in 1409 the Council of Pisa elected 'Alexander V' as rightful Pope. Unfortunately, they did this without persuading the other two popes to resign, so that there were now three popes. The following year 'Alexander V' was replaced by the extremely able 'John XXIII', and this terrible division of Christendom continued for a further seven years. At the Council of Constance in 1414 a determined effort was made to end the scandal. John was ultimately deposed, and Gregory was persuaded to resign. Finally, in 1417, 'Benedict XIII' was declared heretical, and Martin V (elected November 1417) was acknowledged by all parties.

A General Council of the Church that could elect and depose Popes at will was obviously a great threat to the papal position. Martin's successor, Eugenius IV, was faced in the year after his election with the Council of Basle, which he could not avoid. Violent quarrels punctuated this Council, which sat until 1448, and further anti-popes were elected. Nevertheless, unity was once more restored under Nicholas V, a pious, unworldly man, who reigned from 1447 to 1455.



Henry VII, Tudor king of England (1485–1509)

Louis XI of France (1461–1483)

Lorenzo the Magnificent of Florence (1469–1492)

The Turks

These papal squabbles destroyed the last chance the Papacy had of leading a successful new crusade against the Turks. By the time Nicholas V died the Turks had already been two years in occupation of Constantinople. Gradually the Turks moved towards western Europe. Hungary, under her great King Matthias Corvinus (1458–1490), managed, for a long while, to repel the advance of this Asiatic power, but after civil war broke out in Hungary in 1490 the advance was resumed. It reached its climax in 1526 with the battle of Mohacs, after which Hungary was overrun.

CENTURY

Map showing Europe in the 15th century

'Protestant' movement

The Papacy undoubtedly lost a lot of prestige due to its failure to launch a successful crusade against the Turks. But it was, in the long run, to lose much more through the activities of its critics. The most important of these was John Hus, whose protestant doctrines, largely based on those of Wycliffe (see page 2666), had a great following in Bohemia. Hus was summoned to the Council of Constance, where he went under the protection of the 'King of the Romans' (king of Germany), Sigismund. However, the Council of Constance burned him as a heretic. The result was civil war in Bohemia. The Hussites were extraordinarily successful, and Sigismund was unable to conquer Bohemia. Eventually a compromise was reached in 1436, by which the Hussites continued non-Roman practices, such as receiving Communion in both bread and wine.

England and France

The Hussite wars were not the only wars in 15th-century Europe. The greatest of them all, the Hundred Years War, came to an end with a dramatic reversal of fortunes. Under Henry V, England annihilated the French at Agincourt (1415) and gained control of virtually all France. Henry VI was proclaimed King of France in Paris. Roused to a supreme effort by the astonishing Maid of Orléans, Joan of Arc, the French won back all they had lost and much more. By 1453 the only British possession in France was Calais.

In England this war was immediately followed by the Wars of the Roses, in which the Lancastrians and Yorkists fought for the Crown. Eventually a new dynasty – the Tudors – came to the throne in 1485 in the person of Henry VII.

France, under Louis XI, rapidly centralised her administration and built herself into an efficient power. Charles VIII made full use of this efficiency when he plunged into Italy in 1494 (see page 412). By this action he began the long struggle with Spain for power over Italian states like Milan and Naples. The wars between these two giants are, for many historians, the beginning of modern history.

Italy

The Italy which Charles invaded was composed of several independent states. Some of them were dominated by single fabulously wealthy families like the Visconti or Sforzas in Milan, and the Medici in Florence (see page 1086). Under the great Cosimo di Medici and Lorenzo the Magnificent, Florentine culture dominated Europe with painters and sculptors like Leonardo da Vinci, Raphael, and Michelangelo.

Spain

Unlike Italy, Spain finished the century united, for the momentous marriage of Ferdinand of Aragon and Isabella of Castile (see page 2654) united the two major kingdoms. Soon the others (Navarre and Granada) were incorporated. It was largely due to Isabella that Columbus made his epoch-making voyage in 1492, and Spain gained her New World empire.

Germany

In the 15th century there were well over 300 independent states in Germany owing a loose allegiance to the 'King of the Romans'. There was little unity except in north Germany, where the Hanseatic League (see page 2748) of northern towns united in a flourishing trading community. However, several of the states slowly began to improve their administration. The most momentous event was the election, in 1438, of a Habsburg King of the Romans, Albert II. From then until the end of the century the Habsburgs gradually expanded their power and prestige. In 1477 the Habsburgs obtained the Burgundian Netherlands. Maximilian I (1486–1519) greatly extended the Habsburg authority in Germany. He was to be followed by Charles V, through whom the Habsburg family was to dominate Europe.

A 15th-century noblewoman

Lichens are able to grow in conditions too inhospitable to support any other sort of life. They are found growing on rocks in the

LICHENS

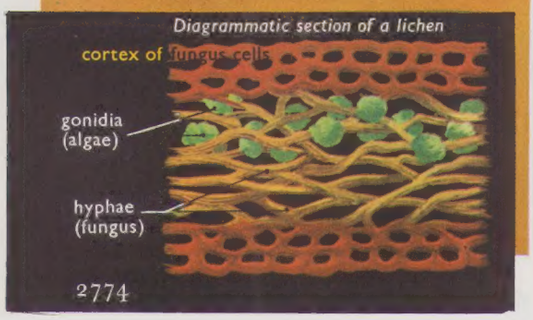
DID you know that a lichen is not really a single plant at all, but a combination of two quite distinct plants living together? This was discovered by the German botanist Schwendener in 1869. His statement was strenuously opposed by the orthodox botanists of the day, who felt that this idea would upset their elaborate classification of lichens; but we now know that Schwendener was correct in his theory.

Every lichen (pronounced 'lyken', not 'litchin') plant consists of a fungus, which usually makes up the main body or *thallus* of the plant, and an alga (see page 2470), whose cells grow in among the threads or *hyphae* of the fungus. Schwendener thought that the fungus was a parasite of the alga, but the modern view is that the two grow in a partnership of the kind known to biologists as symbiosis. The alga, possessing chlorophyll, makes food by photosynthesis (see page 333); while the fungus absorbs nutrients from water, gives the plant a definite structure, and protects it from drying up.

ALGA+FUNGUS=LICHEN

We have seen that a lichen consists of an alga and a fungus growing in intimate association. This is made clear by the fact that both the fungi and the algae that form lichens can be grown separately. It is always difficult to make the fungi grow in the absence of their partners, but this can usually be done if they are grown on a jelly in which plenty of sugars and nutrient salts have been dissolved. The algae, on the other hand, always belong to species which are found living independently. Both green algae and blue-green algae (see page 2471) are found as the algal partners in lichens.

The fungus grows in the form of a tangled mass of threads called *hyphae*; algal cells growing as part of a lichen plant are usually called *gonidia*.



Cup lichen (Cladonia pyxidata). *The apothecia are borne on the edges of little stalked, cup-shaped structures. This is a common species in country districts*

CLASSIFICATION

Lichens are generally classified according to the way in which they grow, and three main types are recognised:

1. **Fruticose.** The thallus is bushy and branching, attached only at the base, and stands out or hangs down from the surface it grows on.
2. **Foliose.** The plant creeps over the surface, but can easily

REPRODUCTION AND GROWTH OF LICHENS

Lichens are reproduced by minute, dust-like spores, which are carried in the air and germinate if they fall in a suitable place. The spores come from the fungus, and are like those of ordinary fungi; the alga plays no part in their production. These spores will grow into fungi if they are cultured on nutrient jelly; in nature they germinate as fungi, but will not continue to grow unless they encounter suitable cells from the many algae which grow independently. The spores of a lichen are usually produced in a small, cup-like structure called an *apothecium*. Some lichens also reproduce by producing little powdery granules, consisting of a scrap of fungus hyphae with some alga cells entangled in them. Such a granule is called a *soredium*, and can grow into a new lichen plant.

Lichens are extraordinarily slow-growing, and are also among the longest-lived plants. This applies especially to the encrusting, or *crustose*, lichens that grow on rocks. The thallus of *Rhizocarpon geographicum* increases about 2 centimetres in diameter over 100 years; patches found growing on rocks in the arctic regions must, by their size, be many hundreds of years old. There seems no reason why they should not go on growing indefinitely.

Antarctic and in the wildest mountain regions

Whatever its true nature, this partnership has produced an extremely successful type of organism. Lichens are hardier than any other kind of plant or animal. They will grow on rock, metal, or even glass, obtaining their food from water, air, and atmospheric dust. They are found in the Arctic and Antarctic, and on mountain rocks far above the snow-line, where no other living things can survive. The one thing lichens cannot stand is atmospheric pollution. Very few of them grow on walls and trees in and near cities, because they are poisoned by the gases and smoke particles with which the air there is always polluted.

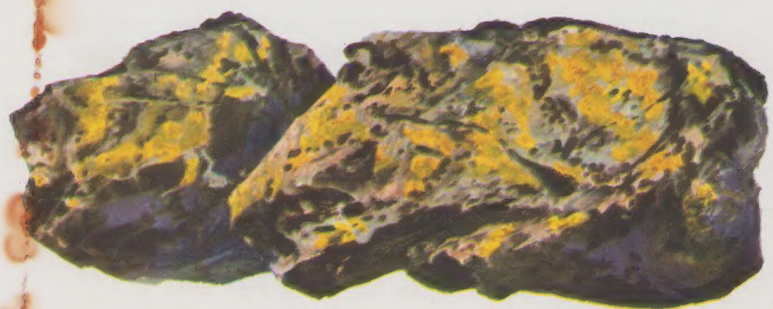
be detached from it.

3. **Crustose.** Lichens of this type are closely applied to the rock or bark, and cannot be removed from it except by brushing or scraping. Some of them look rather like dried paint.

USES OF LICHENS

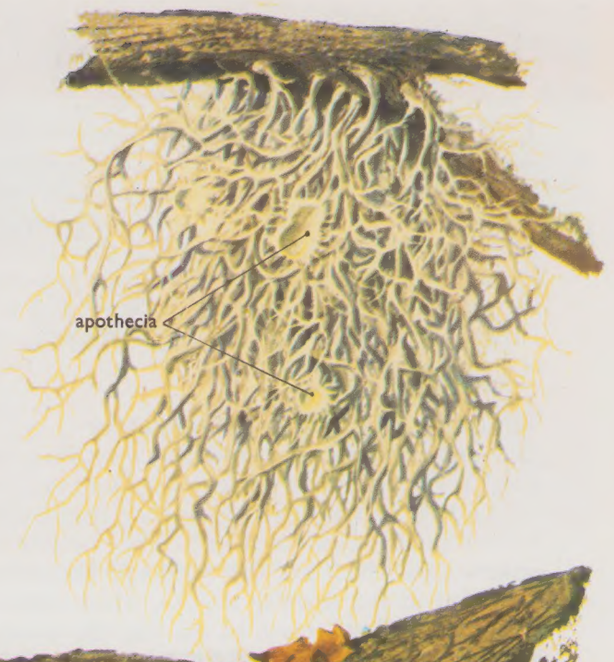
Lichens were once used extensively for making dyes; the chemical colour-indicator called litmus is obtained from lichen. In the arctic tundra a large fruticose lichen grows on the ground and is known as reindeer moss (illustrated on the right), because it is the chief fodder of the reindeer. Some species produce antibiotics which, in certain types of infection, may be more effective than the famous antibiotic penicillin.

SOME TYPICAL SPECIES OF LICHEN



Calopaca citrina. A crustose species that grows on limestone and concrete, producing irregular yellow, powdery patches.

Beard lichen (*Usnea comosa*). A typical fruticose lichen, grey-green in colour, which grows mostly on trees. Two apothecia are shown in the illustration. These lichens are most common in western Britain, in regions where the air is not polluted.



Dog lichen (*Peltigera canina*). A large foliose lichen that grows on the ground and on dead wood.

Reindeer moss (*Cladonia rangiferina*). A lichen of the arctic regions, also found on high mountains in Scotland. It grows on the ground and is the main food of the reindeer.

Iceland moss (*Cetraria islandica*). Common on heather moors in northern Britain. This is one of the few lichens that are edible.

THE COMBINE HARVESTER

EACH harvest time 50,000 combine harvesters roll across the golden cornfields of Britain. It was once said that these machines could never harvest a corn crop satisfactorily in a climate as wet and cold as Britain's. But today they are used by thousands of British farmers to snatch their corn from the fields, almost between the showers. True, corn harvested by combine harvester has often to be dried before it can be safely stored, but this minor inconvenience is greatly preferable to the loss of a whole crop in the fields.

The work of a combine harvester

The name 'combine harvester', or, more frequently, just 'combine', is given to these machines because each carries out the work which, in traditional harvesting methods, was performed by two quite separate machines. They *combine* the work of the *reaper-binder*, which cut the corn and bound it into sheaves, with that of the *threshing machine*, which separated the grain from the chaff and straw. In this way the combine reduces the number of men needed in the fields at harvest time, and it also reduces the risk of losing the crop as it stands stooked in the fields during bad weather.

Combine harvesters are not a particularly new invention – the first were used in Australia as long ago as 1845. Of course, they were then drawn by horses. A little later combines were used in California, and from there they spread to the great wheat-growing areas of the Mid-West and Canada. In Britain, there was considerable opposition to the use of these machines, and even as recently as 1938 only 50 were in use. It was generally thought that British fields were far too small for such bulky equipment, and that in so cool a climate the corn should stand in stooks for at least a week for the grain to dry out. As it happened, neither of these problems has proved insuperable, and it is now agreed that the ability of combines to take advantage of even a single day of good weather outweighs all other considerations.

Two types of combine

Two types of combine harvester – tractor-drawn and self-propelled – are used in Britain at present. The tractor-drawn machines are relatively small, with cutter-bar widths not exceeding 6 feet. The tractor provides the power to pull this machine across the cornfield, but more power is needed to operate the cutting, elevating, and threshing mechanism. This is provided either by a small petrol or diesel motor on the harvester, or by a power-take-off shaft which runs backwards to the harvester from the engine of the tractor.

A self-propelled combine harvester at work in an English cornfield

The advantages of tractor-drawn machines are that they are cheaper, and that the motive power (the tractor) can be used for other tasks once the harvest is gathered. The disadvantages are that the small width of the cutter makes it possible to harvest only a relatively small acreage each day, and that each field must be 'opened-up' by men using scythes.

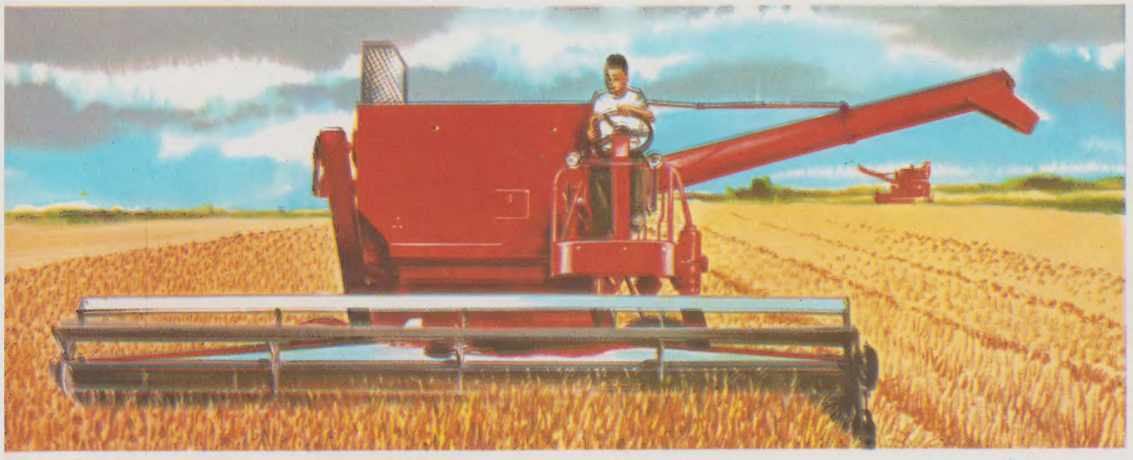
Self-propelled combines vary in size from quite small machines to harvesters with cutter-bars 16 feet wide. As the cutter is always arranged at the front, these combines can cut around the outside of a field without knocking down the corn. This feature and the large acreage which they can handle in a single day are making self-propelled combine harvesters increasingly popular.

Bag or bulk

Almost all of the early combine harvesters which were used in Britain were provided with a small platform, the *bagging platform*, on which two men stood as the machine moved through the corn. The task of these men was to collect the grain into sacks as it issued from the machine. When the platform was full of sacks the combine stopped, and the sacks were taken off. Today, bulk handling methods are becoming increasingly popular, and on many combines the bagging platform has been replaced by a large tank. The grain from the threshing mechanism is lifted into the tank by an *auger*, and the combine need only stop to discharge its load when the tank is full.

Bulk handling

On some modern farms, special vehicles for handling grain in bulk are used to carry the corn from the field. This method has the advantage of needing only a small labour force, and eliminating man-handling of heavy sacks. Indeed, the harvest can be gathered by two men, one on the combine and another carting the grain. The disadvantage of bulk handling is that the grain often has to be dried before it can be stored.



A large self-propelled combine harvester with a 14-foot cutter-bar and a grain tank

How a combine harvester works

All combine harvesters are fundamentally alike in that they have a cutter-bar to cut the crop and a threshing device with which to separate the grain from the straw and the chaff. The way in which these parts are arranged can be seen in the sectional view of a large self-propelled combine harvester, shown in the illustration below.

At the front is the *reel* (1) consisting of five *reel-bats* strengthened at the sides by *reel-braces* (2). From each reel-bat hangs a series of *tines* (3) which comb the standing corn towards the *cutter-bar* (4) and the *platform auger* (5). The angle of the tines can be adjusted by means of the *tine adjuster* (6).

The cut corn is carried into the machine by the *front* and *rear feed beaters* (7 and 8), and so reaches the rapidly revolving *drum* or *cylinder* (9) which presses the heads of corn against the *concave* (10). At this stage, much of the grain falls out of the ears on to the sieves below. This straw is next grasped by the *straw beater* (11) and carried on to the *straw walkers* (12) which shake it vigorously to remove any remaining grain. From the straw walkers the straw goes to the *straw press* (13), at the rear of the combine, where it is tied into bales with *twine* (14) from a large *ball* (15) and allowed to slide down the *straw chute* (16) to the ground. The whole of this mechanism is shielded by a *safety screen* (17).

As the grain falls on to the *sieves* (18 and 19) it is met by a powerful blast of air sucked through the *air filter* (20) by the *fan* (21). The strength of this air blast can be accurately controlled by the *shutter* (22) in the *duct* (23). This control ensures that the air blast removes all the chaff from the grain without blowing the grain off the sieves at the same time.

The grain falls through the sieves and is lifted by the *corn auger* (24) to the *grain-cleaning cylinder* (25), where weed seeds and fragments are removed. The grain then passes into the tank. The *tailings auger* (26) carries unthreshed ears from the sieves back to the cylinder for rethreshing. A *weed auger* (27) deals with weed seeds.

Control of the combine is maintained by the driver from his *seat* (28) on the *driver's platform* (29). The *steering wheel* (30) operates through the *steering linkage* (31) on the *rear wheels* (32), as do the *foot* and *hand brakes* (33 and 34). Speed is controlled by the *gear* (35), which regulates the *driving wheels* (36). The reel is operated by the *reel control lever* (37), and the platform height by the *platform lever* (38). The *engine air intake* (39) is placed away from dust.

Tractor-drawn combine harvester with a 6-foot cutter-bar

Comparison of the two types of combine

The amount of work which a combine harvester can do each year depends on its size, on the weight and condition of the crops on which it is used, and on the ground over which it is worked. This table is a guide to the capabilities of a tractor-drawn machine and a much larger self-propelled machine, working under average conditions.

	Tractor-drawn	Self-propelled
Width of cut	4 to 6 feet	8 to 16 feet
Acres per hour	1	1½–2
Acres per season	120	240
Tons of grain harvested per hour	3	6
Tractor horse-power needed	25 to 30	–
Combine engine horse-power	25	60–90
Working speed	2 m.p.h.	2 m.p.h.
Cylinder speed	1,000–1,400 r.p.m.	600–1,100 r.p.m.
Tank capacity in bushels	30	55
Unloading time in mins	1	1½
Useful working life	8 to 12 years	8 to 12 years
Approximate cost	£750	£3,000

Crops suitable for combine harvesting: wheat, barley, oats, rye, peas, beans, clover, rape, grass seed, kale seed, and beet seed. Number of hours of weather suitable for combine harvesting during an average English summer: 150.

Sectional view of a large self-propelled combine harvester, showing the way in which the corn is threshed and the grain separated from the chaff

ITALY: 1919-1939

THE tragedy of Italy was that she tried to run before she could walk. After the First World War Italy, who had belatedly joined the allies in 1915, expected to be treated as a major power. Consequently she felt humiliated when her claims were ignored or deferred, while Britain, France, and the United States deliberated on the great questions of the day. At the Treaty of Versailles (June 1919) Italy gained the Trentino, pushed her frontier to the top of the Brenner Pass, and also obtained Trieste (see page 2742). Yet because other demands, notably for Dalmatia and the port of Fiume, were rejected, the Prime Minister, Orlando, was constantly criticised by right-wing 'nationalist' politicians like D'Annunzio and Mussolini.

Most Italian politicians in the years following the war showed a hopeless grasp of what was wanted. Italy was an impoverished country. Much of her population, particularly in the south, was backward, illiterate, and lawless. Yet the 'nationalists' fixed their eyes on a policy of 'glory', while the rest were too inept to take a strong line with the growing discontent of the nation.

The Italian revolution

In 1919 the flamboyant D'Annunzio marched with a few followers into Fiume and held it 'against the world'. He was allowed to remain in Fiume for a whole year, hurling abuse at his own 'defeatist' government. Mussolini, who formed the Fascist Party in October 1919, watched this event with interest. In a very few years he would defy the Italian government and march, not on Fiume, but on Rome.

Benito Mussolini – brought disaster for Italy

The rise of Mussolini

Despite the trumpetings of D'Annunzio, the Italian nation as a whole was more concerned with poverty and unemployment than with territorial conquests. Anti-government factions grew, the largest being the Socialists and the Communists. There were innumerable demonstrations against the government, now dominated by the moderate *Populari* Party. There were many strikes and lock-outs (employers' strikes), and rich businessmen in northern Italy became alarmed. After wavering for some time Mussolini finally threw in his lot with the extreme 'right-wing' and became a sworn enemy of the 'left'. Fights and murders among Mussolini's black-shirted *squadri* and the 'left-wingers' became increasingly frequent, and the businessmen came to regard Mussolini as their sole protector against the 'red peril' of Communism. D'Annunzio had lost his prestige when he left Fiume after the Treaty of Rapallo in 1920 (which made Fiume a 'free city'). Soon Mussolini controlled all 'right-wing', anti-Communist, and anti-government elements.

In October 1920 a general strike and lock-out resulted in a dramatic 'occupation of the factories' by the workers, who tried to run them without the management. Not surprisingly, the Fascists gained strength in many northern towns, notably Milan. Mussolini began to talk of overthrowing the government by force, and in October 1922 his followers 'marched on Rome'.

The new Prime Minister, Facta, gave orders for the army to repel the Fascists. But the frightened Victor Emmanuel III unconstitutionally and unpardonably refused to ratify Facta's order, and invited Mussolini to become Prime Minister. At that time the Fascists had only 35 representatives in the Chamber of Deputies.

October 1922: Mussolini's Fascist

The supremacy of Mussolini

Benito Mussolini was one of the greatest turncoats in history. He had been a socialist before he realised that power could best be obtained through a 'reactionary' policy. Without private morals and violently anti-clerical, he found it convenient to pose as a true son of the Church, once he was in power. And this man, who had once fled to Switzerland to avoid call-up and had served a prison sentence for pacifism, became a champion of belligerence, aggression, and war. The truth was that Mussolini had no real philosophy other than the acquisition of power, and nor had Fascism. Fascism (meaning 'bundle', a bundle of rods being the Fascist symbol) had no particular doctrine or 'crusade' (like Nazi racialism) to carry into effect. Mussolini himself became the *raison d'être* of Fascism. 'Mussolini has a reason for everything' was a Fascist slogan. And all the trappings of dictatorship – the one-party system, propaganda, police, salutes – came in as the *Duce* (leader) gained control of Italy.

The Fascist doctrine, evolved once Mussolini was in power, was that of the 'corporate state', in which every organisation and individual was to work, as directed, in the public interest. Trade unions were replaced by 'Fascist Workers' Syndicates'. Showy new buildings were erected, *autostrade* (motorways) were constructed, and marshes were drained. Mussolini made fantastic boasts. He said that by 1960 Italy's population would have grown from 40 million to 60 million; he gave huge family allowances and imposed an excessive 'bachelor tax'. But, in fact, Mussolini's economic policy was a failure. His

'black-shirts' march on Rome. Victor Emmanuel lost his nerve, and so Mussolini came to power

Von Ribbentrop and Ciano – Foreign Ministers of Germany and Italy

discouragement of emigration increased unemployment, while his devaluation of the *lira* badly hit the export trade. His ruinous expenditure on war and armaments disrupted the economy further. After 1933 the government stopped issuing official trade figures and unemployment rates. Yet it would be untrue to say that Mussolini was universally unpopular. Certain political opponents like Matteotti were eliminated, but there was surprisingly little organised opposition. After all, the slump of the 1930s was world-wide, and Mussolini's government was at least more stable than the old parliamentary regime. He did have some solid achievements. He virtually suppressed Mafia brigands in Sicily, and his bombastic speeches restored Italian self-respect. In addition, he had one remarkable success – the Concordat with the Papacy in 1929, by which the Vatican became a sovereign state under the Pope.

Mussolini became increasingly obsessed with his own 'intuition' and surrounded himself with flattering nonentities. In 1936 he made his son-in-law, Ciano, Foreign Minister. Ciano was no fool, but he shared Mussolini's aggressive intentions.

Mussolini's foreign policy

Mussolini lost no time in showing the world that the Fascists were men of action. As early as September 1923, when a gang of Greeks murdered an Italian, he demanded huge damages and occupied Corfu. He was compelled to evacuate Corfu by the League of Nations, but nevertheless received excessive monetary compensation. In 1924 he finally annexed Fiume, and made himself the acknowledged leader of the 'revisionist' powers like Hungary and Austria who wanted to 'revise' the Treaty of Versailles. Thus Mussolini put into effect his slogan, 'Italy won the war, but lost the peace', by associating himself with the defeated powers.

Mussolini had always supported the Nazis, and when Hitler came to power in 1933 friendly relations between the dictators were at once established. Yet this endangered Italy's greatest gain from the First World War – the elimination of her hereditary enemy, Austria. If Austria ever again became powerful, or was annexed by a major power, Italy would at once be threatened. Indeed, in June 1934 Mussolini massed troops on the Brenner frontier as a warning to Hitler to stay out of Austria. But gradually he came under Hitler's spell. Both countries, with their aggressive, brutal dictatorships, had much in common.

On 3rd October 1935 Mussolini invaded Abyssinia. The League of Nations imposed trade 'sanctions' (prohibiting trade) which proved totally inadequate to stop Italy. Abyssinia soon collapsed under the attack of modern weapons, including poison gas. Hitler was one of the few leaders not to impose the League's sanctions.

The Spanish Civil War brought the dictators still closer together. Both gave help to the Fascist Party in that war, and meetings between the dictators and their Foreign Ministers became the concern of Europe. In 1937 the Rome-Berlin 'Axis' was proudly proclaimed. Mussolini joined Hitler's anti-Comintern (anti-Communist) pact with Japan, and left the League of Nations. In 1938, under the influence of his Nazi friends, he declared his first anti-Jewish laws.

Yet despite Mussolini's vigorous support of Hitler he was secretly afraid of becoming a mere hanger-on, and in 1938 he told Hitler that he would not be ready for war for at least three years. Instead of waiting for him, Hitler became increasingly aggressive. Mussolini played a restraining part at Munich in 1938, but he was torn between the desire to hold back and the desire to rival Hitler. In April 1939 he invaded Albania, and in May, for no particular reason, he converted the Axis into a formal alliance called the 'pact of steel'. As war neared over Poland Mussolini once more urged caution on Hitler, but the Fuehrer's replies were evasive. Mussolini had no idea that German troops were being slowly moved towards the Polish frontier, nor was he told about the dramatic Nazi-Soviet pact which broke on Europe 'like a bombshell' in August. But characteristically the proud *Duce* could not stand aside while Hitler smashed his way through France and dominated Europe – and so, soon after, Mussolini took his country into a conflict that was to prove disastrous.

DREAMS

DID you dream last night? If so, your dreams were probably about events which happened yesterday, and it is likely that you dismissed them merely as your memory working while you slept. When, 4,000 years ago, Pharaoh dreamed of thin cattle eating fat cattle and thin ears of corn eating full ears of corn, he was far too superstitious to dismiss his dreams so readily. Only a complete interpretation could set his mind at rest.

Everyone will recall how Joseph was brought from Pharaoh's dungeon, and how he revealed that the seven fat cattle and the seven full ears of corn in the dreams were seven years of wonderful harvests in the land of Egypt. The seven thin cattle which ate the fat cattle, and the seven poor ears of corn which devoured the full ones, were seven years of famine which were to follow. Pharaoh was so delighted with this interpretation that he appointed Joseph to the post of 'prime minister'. Moreover he made Joseph responsible for storing surplus food, harvested in the good years so as to feed the Egyptians during the years of famine.

Few people now are as superstitious as Pharaoh, and even fewer would claim, like Joseph, that they were able to interpret dreams with Divine assistance. Most see their dreams as fragments of their waking life which are remembered in sleep. If the details of a dream are inaccurate or the images unduly vivid this is not surprising; memory can lapse, and man has great imagination. Others believe that dreams are caused by sensations received during sleep. A wayward sheet falling over the sleeper's head may become a great wave as he bathes in the sea; the tick of a bedside clock may suggest the blows of a sledgehammer. Dreams of this type, it is said, often follow large meals eaten late at night; and certain foods, particularly cheese, are thought to make us dream in this way.

Scientific interpretation

For the psychologists, who study the working of the normal human mind, and for the psychiatrists, who study the working of the deranged human mind, our dreams have a different significance. They are the way in which memory brings back to our attention problems we have not solved in the past – even the very distant past. Sometimes, in the dream, the problem may be solved and the dreamer thereby given confidence. Sometimes the problem is never solved either in the dream or in real life, and, in consequence, the dream recurs time and time again, usually to the discomfort of the dreamer.

Some people say that they dream every night, others that they never dream at all. Those who deny that they dream are probably mistaken; it is likely that they dream like everyone else but cannot remember their dreams when they awake. Almost everyone can recall an occasion when an event during the day has suddenly brought back an utterly forgotten dream of the previous night. One says, 'Oh, I've broken my dream.'

Sigmund Freud, who thought dreams protect us from unpleasant thoughts

Measuring dreams

The time taken to experience a dream was at one time thought to be very short. Even the longest dream, so it was said, occupied only a few seconds.

Recently this idea has been challenged by experiments performed with an instrument called an *electroencephalograph* which measures the electrical activity of the brain, the 'brain-waves', through the skull. This instrument consists of small electrodes, which are placed on the outside of the head to pick up the waves, and a device to amplify and record them on a roll of paper.

In the experiments the electroencephalograph was used to observe people's brain-waves throughout a long period of sleep. When the subjects were sleeping deeply it was seen that the waves were large and that they were well spread out. At intervals of about 90 minutes, however, the waves became smaller and more frequent, and at the same time the subjects began to sleep lightly and less restfully. This light sleep and the small waves often continued for as long as half an hour before deep sleep and the large slow waves returned.

If the subjects were woken up when they were sleeping deeply only a few said that they were dreaming, and even these could recount their dreams only sketchily. If, on the other hand, the subjects were woken up when they were sleeping lightly they very often said that they were dreaming, and could describe the events in their dreams in great detail.

It seems as if dreaming is something which everyone does at intervals throughout each night's rest and that it is associated with periods of light sleep and a characteristic type of brain-wave. Furthermore, as the night passes, the periods of light sleep become longer and longer until by dawn they last for up to half an hour.

The soldier dreams that peace has come at last

The criminal dreams of the day when he was young and innocent

A set of Victorian prints illustrating dreams. In these,

If, as Pharaoh believed, our dreams foretell the future, then their interpretation is obviously important. So, too, is it if, as the Ancient Greeks believed, our dreams are messages from the gods. It is not surprising that Joseph was well rewarded for his skill, and that those claiming to interpret dreams have often received money for their services. Even today a silver coin across the palm is needed to persuade a gypsy to perform this simple task, and the services of a psychoanalyst are by no means inexpensive.

The birth of psychoanalysis

For the unsuperstitious, there are several rather sophisticated approaches to the problem of dreams. One, the best known, was initiated by a Jewish doctor whose name is now a household word. Sigmund Freud (pronounced Froid) was born at Freiburg in Moravia in 1856. When he was three years old his parents, who were very poor, moved to Vienna, and it was at the university there that Sigmund later qualified in medicine.

In his early years Freud practised as a neurologist, but after a visit to the clinic of the great French physician, Charcot, in Paris he decided to abandon the study of the brain and investigate the mind instead. In consequence, the remainder of his professional life was spent developing the system now known as *psychoanalysis*. A victim of Nazi persecution, Freud left Vienna in 1938, and died in London in the following year.

Freud's theory

Freud taught that the purpose of a dream is to protect the sleeper from unpleasant thoughts which might disturb his rest. Thus a child who longs for a bicycle, but who is refused one by his parents, dreams of riding on the most wonderful bicycle ever made. The child's wish for a bicycle is gratified, and his sleep is undisturbed by longing. The wishes and desires of adults are much more complicated, and, in consequence, their dreams are more complicated too. Frequently the objects which adults see in their dreams are not the troublesome objects which occupy their waking hours but more acceptable objects, or *symbols*, which represent them. A man's bullying father may appear in a dream as a king, or his disobedient children may appear as little animals.

In his attempts to explain all dreams, Freud found it necessary to complicate his theory so much that many scientists find it not wholly credible. Furthermore, like much of the study of the mind, the theory cannot be supported by laboratory experiments. Nevertheless, Freud's ideas, and those of others that have sprung from them, are serious and worthwhile attempts to explain a puzzling human problem.

DID YOU KNOW?

1. When you dream your eyeballs move about – sometimes quite violently.
2. People who are prevented from dreaming for several successive nights (although they are allowed to sleep until they start dreaming) become very nervous and irritable.
3. Some people believe that they dream in colour, while others are convinced that they only dream in black and white.
4. Dreams sometimes seem to be *telepathic* – someone may dream of an event which he cannot know about at the time, but which later proves really to have happened.
5. Some drugs, like opium, give the people who take them pleasant dreams. Unfortunately this may lead to people becoming addicted to the drugs in their attempts to have such dreams more often, and drug addiction is very dangerous.

Some notable dreamers

Although the dreams which are recounted in the story of Joseph are the best known of all, there are many others, some factual and some fictional, which are almost as famous. One well-known real dream was that which the German chemist F. August Kekulé experienced while writing his textbook. At the time (1865) he was greatly puzzled by the formula for benzene, for, though he knew that the benzene molecule contained six carbon atoms, he could not visualise the way in which they were fitted together. Despairingly, he left his work and pulled his chair to the fire. Within a few moments he was asleep. In a dream he saw a snake which curled round to form a complete circle, and immediately he realised that the carbon atoms in benzene were arranged in the same way: a chain of six atoms bent round to form a ring. Some years later Kekulé visited London, and it was there that he had a second dream which suggested to him the basic ideas of chemical valency. London transport at that time must have been very comfortable – his second dream took place on a London bus.

Another famous dream, though less serious than that of Kekulé, was experienced by the poet Samuel Taylor Coleridge. This strange man was in the habit of taking opium, and in his dream he visualised the delights of an imaginary kingdom called Xanadu. The dream is recounted in Coleridge's poem *Kubla Khan*, which is unfortunately incomplete. Coleridge was interrupted by a visitor from Porlock before he could set all of his dream on paper, and when he returned to the poem the imagery, dreamlike, had vanished.

Lastly there are fictional dreams. Should you be one of the many who think that their answer to the question which begins this article is 'No', then you can at least share in another's dream. What better way can there be of doing this than to share the wonderful dreams of Lewis Carroll's 'Alice'?

The merchant dreams that his ships are lost at sea

The murderer dreams that his victim returns to haunt him

various people's hopes, desires, and anxieties are expressed

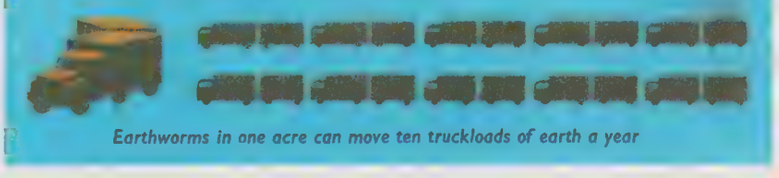
THE EARTHWORM

EVERY boy who enjoys a day's fishing knows that he can find earthworms for bait without much trouble; a few spadefuls of earth dug up almost anywhere will produce them. A thrush or blackbird hopping about on the lawn pulls a worm out of the turf every few minutes. Worms must, in fact, be extraordinarily numerous, but few people realise how fantastically abundant they really are. Agricultural research workers have established that in old, rich pastures, where earthworms thrive best of all, there may be as many as 3 million of them to the acre. Putting it another way, the total weight of a herd of cattle grazing on a pasture of this kind is generally less than that of the earthworms in the soil underlying it.

The worms must obviously have some effect on the soil they inhabit in such huge numbers, and it is now well known that this effect is beneficial, and earthworms are the farmers' friends. The first person to realise this seems to have been the Hampshire naturalist, Gilbert White. In a letter written in 1777 he says: 'Worms seem to be the great promoters of vegetation, which would proceed but lamely without them . . .', and describes how their burrowing loosens the soil, and how they help to keep it fertile.

The earliest systematic study of earthworms was made by Charles Darwin (see page 1320) a hundred years later, and his book on the subject drew the attention of both scientists and farmers to the part that earthworms play in the soil. Darwin collected worm-casts (the excrement of worms that have been eating soil) on measured areas of land, and found that in the course of a year they amount to about 10 tons per acre. Commenting on this, Darwin wrote: 'The plough is one of the most ancient and most valuable of man's inventions; but long before it existed the land was in fact regularly ploughed, and still continues to be thus ploughed, by earthworms.'

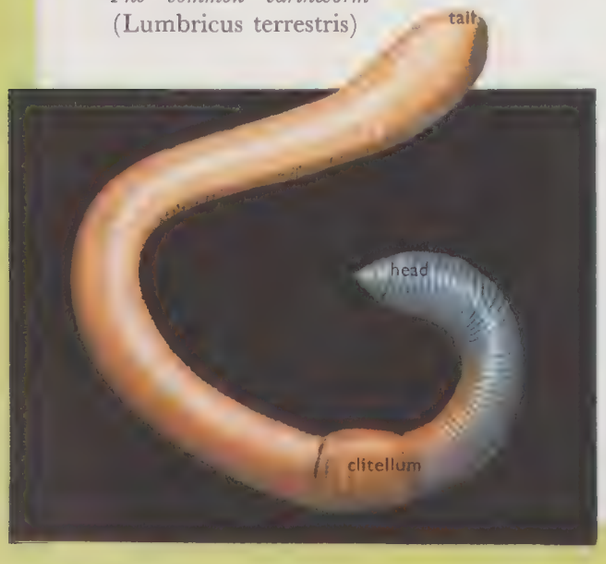
Section of a cubic foot of earth, illustrating the activities of earthworms


The earthworms in an acre of grassland would fill a large truck
Earthworms in one acre can move ten truckloads of earth a year

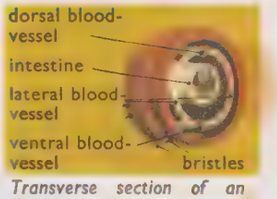
Some facts about earthworms

In Britain there are about 25 species of earthworm; since the largest of them, *Lumbricus terrestris*, is also one of the most common, it will be convenient to describe this species, remembering that the others are similar to it in their main features.

The common earthworm
(Lumbricus terrestris)



A few minutes' digging in any garden with fairly heavy soil will enable you to find a specimen of this worm, which is often 8 inches long and sometimes nearly 1 foot. As soon as you look at it, you will see that one end (the front) is tapered and dark in colour, and the other end is paler and flattened. The first thing shown by a close examination is that the body consists of a large number of rings, separated from each other by grooves which encircle the body; this is the most characteristic feature of the phylum Annelida or Segmented Worms, to which the earthworms belong. Each of the grooves between the rings marks the edge of an internal partition, separating one compartment or segment of the body from the next. The worm has between 100 and 160 of these segments, and to a great extent the organs of the body are repeated in each segment, so that the animal consists of a series of similar units. But the popular theory that when a worm is cut in half both parts will survive is only true in exceptional cases.



Transverse section of an earthworm

Diagram of the front part of an earthworm (from above)

Earthworms improve soil drainage

WHERE THEY LIVE

True earthworms (Lumbricidae) all live in the soil. In cold or dry weather they burrow 6 feet deep or more, and remain inactive until conditions improve.

The worm's mouth is underneath the second segment at its front end, but it has no eyes, or feelers, or sense organs of any kind. But the skin of a worm is sensitive to light; exposure to sunlight paralyses and eventually kills worms, due to the effect of the ultra-violet rays. If you find a worm half out of its burrow at night and shine a torch on it, it will retreat hurriedly into the earth, unless the torch has a red glass on it. In this case there will be no reaction, as worms cannot perceive red light.

The worm's body bears numerous tiny bristles (eight on each segment), by means of which it is able to crawl. The bristles can be pointed forwards or backwards. If they are directed backwards, and the worm elongates its body, the head end will slide forwards, while the tail end, held by the bristles catching against the soil, stays still. If you look at the illustration in the top right-hand corner of this page you will see how the earthworm moves.

The worm is lying extended ①; the head end is anchored by the bristles and the tail is drawn up towards it ②. When it elongates again ③ the whole worm has moved forwards. To move back, the worm performs the same movements with the bristles directed forwards.

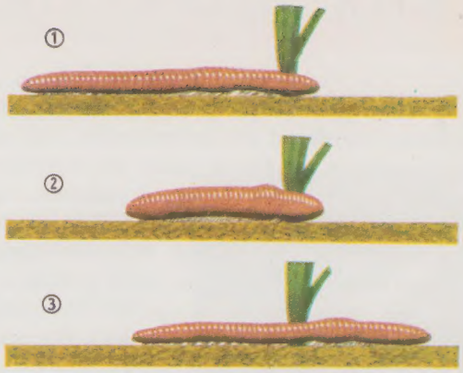


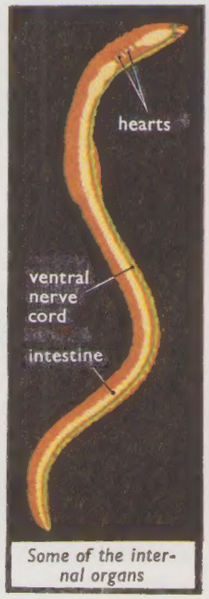
Diagram showing how the earthworm crawls

How they feed

Earthworms feed in two quite distinct ways. If you examine your lawn in rainy weather you will often find dead leaves that are standing up with one end pulled into a hole in the earth. For worms come out at night and search for leaves, drag them partly into their burrows, and feed on them there. Charles Darwin found that they prefer certain kinds of leaves, including those of carrots and cabbage.

In dry weather, or when food is scarce, worms burrow by eating their way through the soil and swallowing large quantities of it. They extract a certain amount of nourishment from the soil, and then void the rest from their hinder end. Some kinds of worm come to the surface to void the soil they have eaten; the familiar worm-casts are formed in this way.

The intestine of an earthworm runs the whole length of its body, and is not segmented as its skin and some of its internal organs are.



Some of the internal organs

CLASSIFICATION

Species: *terrestris*
Genus: *Lumbricus*
Family: Lumbricidae
Class: Oligochaeta
Phylum: Annelida

How they reproduce

An adult earthworm can be recognised by a swelling just in front of the middle of the body, called the *clitellum*. When the eggs are ready to be laid a sheath of slime forms round the clitellum, and the worm moves backwards, sliding the clitellum towards its head. When the sheath comes opposite the ovaries the eggs are passed out into it. Finally the worm crawls out of the sheath, the ends of which purse up to form a cocoon in which the eggs hatch.

THE WORM AS AN AGRICULTURIST

Here are some of the ways in which the worm improves the soil. First, when worms 'eat' the soil, they avoid large particles of sand or grit, so that they are constantly bringing fine-grained soil to the surface, while they leave the coarser soil below. Secondly, they take a great deal of vegetable matter underground in the course of their feeding. Finally, their burrows provide drainage and aeration in the soil, and make it easier for the roots of plants to penetrate. It is on grassland and pasture that worms are most abundant and do most good.

Earthworms sometimes burrow to a depth of 6 feet or more

THE EMPEROR THEODOSIUS

IN AD 390 the people of Thessalonica, dissatisfied with their German garrison, rose up, murdered the commander, and killed many other officers. When the Emperor Theodosius the Great heard the news he ordered a terrible vegeance; thousands of the citizens – men, women, and children – were massacred by the German troops.

Soon afterwards the Emperor went to the great church of Milan to worship. As he was entering, the Bishop, Ambrose, appeared and stopped him. A man who was polluted with the blood of so many people, said Ambrose, might not take Holy Communion – even if he were the Emperor. Theodosius must publicly admit his guilt for the massacre, and perform a severe penance. And the Emperor submitted. For several months he was not even allowed to wear the Imperial regalia. And when he was again admitted to the Communion table the new power of the Church had been clearly demonstrated.

Theodosius was a devout Christian, and crushed the last remnants of paganism. This was one of the achievements which earned him the description 'the Great'.

Theodosius and the Goths

Theodosius's rise to power began in 378 when the Emperor Valens was killed and the Roman army routed by the Goths at Adrianople. Gratian, who was Emperor in the west, appointed Theodosius Augustus of the eastern Empire. Although he did not in name rule over the whole Empire until 393, Theodosius soon became its real ruler.

His first job was to pacify the Goths, a Germanic tribe which had migrated south from the shores of the Baltic Sea to the northern shore of the Black Sea. From there they threatened the Empire throughout the 3rd and 4th centuries. But they were not always at war with Rome; and Gothic prisoners of war served faithfully in the Roman army. In 376 the Goths were forced to beg for Roman help. They asked to be allowed to cross the Danube and settle inside the Empire, in order to escape from another, even fiercer, tribe which had pushed westwards from Asia – the Huns. The Goths were given permission to cross the river and settle in Moesia, and in return they agreed to serve in the army.

Within a year or two, however, they were discontented and rose in revolt. It was then that they won their great victory at Adrianople. After this it looked as though the whole of the Empire in the east was open to them, and soon they were at the walls of Constantinople.

Theodosius – he controlled the Empire from the east

It was at this critical time that Theodosius became Emperor in the east. He soon succeeded in bringing the Goths under control, but he went further than this. The Goths were too many and too strong to be kept down permanently by a few minor defeats. Theodosius started a new policy of active friendship with them; he made treaties, gave them various privileges, and appointed them to important posts in the army and the administration.

In this way the army became more and more a Gothic, or German, army. This policy was forced on Theodosius, but there was a heavy price to pay for it. Although the Goths were acquiring something of the Roman culture and civilisation, and although Christianity was spreading among them, they were still barbarians and were dangerous allies. In the army they learned Roman tactics and discipline – some day they would be able to turn this knowledge against the Empire.

Theodosius and the Christians

The Emperor Julian the Apostate (see page 2762) had tried to restore paganism, the worship of the old gods. After his death in 363 there was religious freedom for both Christians and pagans, but Theodosius was determined to destroy paganism, and succeeded. Paganism ceased to exist as an organised religion, although a few pagans still worshipped their gods in secret.

Theodosius also fought Christians whose beliefs were different from his own. In these times the Church was split by serious disagreements over doctrine, which Theodosius tried to stop by establishing by law who was and who was not a member of the Catholic Church. From now on only those who upheld the Nicene Creed were true believers and Catholics. All others, like those who followed the teaching of the Alexandrian priest, Arius, were 'heretics'. They were forbidden to meet and worship, and the true Christians took over all the churches in the Empire.

Theodosius genuinely wanted to restore unity to the Church. In 381 he summoned the second Ecumenical Council, a great assembly of the elders and bishops of the whole Church, who met at Constantinople to decide on the true teaching of the Church and to denounce heresies. But religious disputes did not cease because of Theodosius's policy. Indeed they increased and multiplied after his death. Perhaps his methods were the wrong ones. Theodosius wanted to impose his own views on the Church by virtue of his power and authority as Emperor. But the Church was too vigorous to accept any solution that was imposed on it, and did not grow up naturally within the Church itself.

Theodosius was the last to rule over a united Roman Empire; he controlled two 'puppet' emperors in the west, and when the second was murdered in 393 he made his younger son, Honorius, Augustus. When he died in 395 he left the Empire to his two sons: the east to Arcadius, the west to Honorius. Although the Empire remained one in theory, the two halves in fact became more and more separated. The east prospered; the west declined before the invading barbarians.

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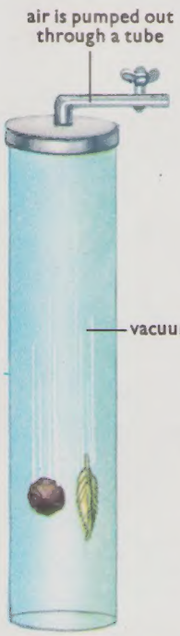
or directly observable with the human senses or with some instrument such as a microscope. For example, the rolling of a ball down an inclined plane as it moves through the air under the influence of gravity comes under classical physics.

When we try to investigate the basic structure of matter we find that everything is made of atoms, and the atoms themselves are made up of even tinier particles, called protons, neutrons, and electrons. Some of the laws which govern the movement and properties of these particles are the same as in classical physics, but others are far more complex and quite different. These new laws are meaningless if we try to use them to describe the properties of large pieces of material; they are only of use for describing the tiniest particle of matter. These are the special laws of nuclear physics.



Bodies in a vacuum fall at the same rate

The experimental method

The first acknowledged experimenter in physics was Aristotle, a Greek philosopher born in 384 B C. He had few instruments with which to make measurements, and so he came to many incorrect conclusions. Unfortunately belief in his genius was so great that few people questioned his theories. However, the Italian astronomer and scientist, Galileo Galilei (1564–1642) was unwilling to accept Aristotle's ideas. In particular, Aristotle had stated that the heavier a body is, the faster it falls through the air. Galileo stated that all falling bodies would descend at the same rate, were it not for the resistance of the air which can slow down some very light ones like feathers. He is said to have proved this by dropping two unequal weights from the top of the leaning tower of Pisa. The weights were released together, and hit the ground together. The resistance of air to a very light object shaped like a feather is large compared with its weight, and it falls very slowly; but a stone and a feather will fall at the same rate in a vacuum.

Galileo's experiments marked the beginning of the investigation of natural phenomena by the experimental method. This means taking precise measurements of a process under accurately known conditions. In this way the laws of nature have been discovered, and put to use for the benefit of mankind.

Classical physics

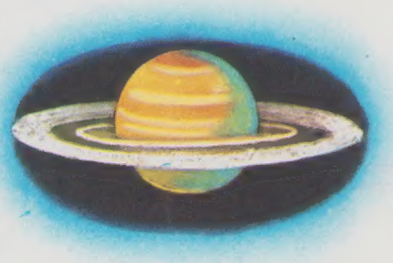
Classical physics can be divided into five major sections. These are: mechanics, the study of the movement of bodies; heat and thermodynamics, the study of heat and its effect on matter; acoustics, the study of sound; optics, the study of light and lenses; and electricity and magnetism, the study of the electrical and magnetic properties of materials and the links between them. Many phenomena in physics involve one or more of these sections. We will now consider two of them. These are geophysics and astrophysics.

Geophysics

Storms – geophysical phenomena

Let us suppose we want to discover the reason for a thunderstorm. We would need to know about light (lightning flash), electricity (which causes the flash), thermodynamics (the ice and rain in the clouds), and mechanics (the violent wind). The storm is just one of many natural phenomena which affect the earth and its atmosphere. The study of these phenomena is called geophysics. It can be divided into several branches: seismology (study of earthquakes), geodesy (study of the shape of the earth), meteorology (study of atmospheric phenomena and weather), and so on.

Astrophysics



Saturn's atmosphere is studied by astrophysicists

The atmosphere of Saturn is made up of hydrogen, methane, and ammonia. How can we tell this of a planet 800 million miles away at its nearest? If the sunlight reflected from the planet is passed through a prism, it is split up into its spectrum of colours. Superimposed on a continuous band of colour from red to violet are many black lines. Each element or compound has its own characteristic set of lines, and by accurately measuring them it is possible to discover the elements and compounds in the planet's atmosphere from which the light is reflected. The analysis of spectra is called spectroscopy. This is the most important tool used in astrophysics, the study of the stars, planets, and galaxies.

Applied physics

Once physicists have experimented and established the laws and principles of nature, they can be used for practical purposes. The early electric motors and dynamos of Faraday were scientific toys of no practical use. However, as soon as their working was fully understood, the way was open for engineers and applied physicists to take the results of the early experiments and use them to construct the giant turbo-generators which now provide our electricity. Early experiments in radioactivity were performed because physicists were curious to discover the inner workings of the atom. It is very unlikely that they realised that their work would lead to the manufacture of nuclear bombs and power stations.

Before a jet airliner could be made years of research had to be carried out and many problems solved. The metal had to be strong enough to withstand enormous stresses, yet light enough to enable the plane to fly. Its jet engines had to be designed to give as much power as possible from as little fuel as possible. Its electronic instruments had to be reliable and work without an

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GLOSSARY OF PHYSICAL TERMS

Metre: the distance between two lines on a rod of platinum-iridium metal which is kept in Sèvres, France. It is approximately equal to one forty-millionth part of the earth's circumference; 1 metre (m)=100 centimetres (cm).

Kilogram: the mass of a cylinder of platinum-iridium kept in Sèvres, France; 1 kilogram (kg)=1,000 grams (g).

Second: one 86,400th part of a mean solar day.

Velocity: the speed of a body in a specified direction, usually measured in centimetres per second.

Weight: the weight of a body is the force with which the earth attracts the body.

Density: the density of a substance is its mass (in grams) divided by its volume (in cubic centimetres).

Specific Gravity: this is the ratio of the density of a substance to that of water when both are expressed in the same units.

Pressure on a body is the thrust it experiences – usually expressed as dynes per square centimetre of its surface.

Standard Atmosphere: a unit of pressure; it is equal to a pressure of 1,013 dynes per square centimetre. It is the pressure exerted by a column of mercury 76 centimetres high.

Compressibility: the capacity of a body to diminish in volume when it is compressed.

Element: a collection of atoms of one type which cannot be decomposed into any simpler units by any chemical means.

Atom: the smallest part of any element which still retains the chemical properties of that element.

Molecule: the smallest part of a substance, other than an element, which can exist free and still exhibit all the chemical properties of the substance.

Temperature: the intensity of heat in a body.

Calorie: the quantity of heat required to raise the temperature of one gram of water from 14·5°C to 15·5°C.

Specific Heat: the quantity of heat required to raise 1 gram of a substance by 1°C.

Conductivity: a measure of the ease with which heat or electricity will flow through a body.

Expansivity: the extent to which the size of a body increases or decreases when it is heated or cooled.

Absolute Zero: the lowest temperature that can possibly exist. It is equal to 273·15° below zero on the Centigrade scale.

Nucleus: the positively charged core of an atom.

Proton: an electrically positively charged particle of matter which is found in the nucleus of the atom together with neutrons.

Neutron: an electrically neutral particle of matter found in the nucleus of an atom.

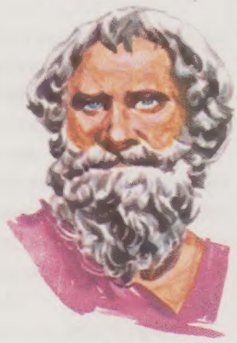
Electron: a particle of matter which carries a negative electric charge. One or more electrons revolve around the nucleus.

Radioactivity: the property of some unstable atoms, particularly those of higher atomic number than uranium, of emitting electrons, neutrons, protons, γ rays, and other sub-nuclear particles with great speed.

error for many thousands of hours. These are just a few of the problems in applied physics that had to be solved before the first prototype airliner left the ground.

The history of physics

The contributions of ancient civilisations to physics, as we know it today, were very few. The main skills of ancient peoples were in building and what we would now call civil engineering. The views of Aristotle were, as we have seen, incorrect and misleading. The first serious contribution to physics was made by Archimedes (287–212 B C), a mathematician from Syracuse. He investigated several mechanical machines including the lever, but he is perhaps best known for his 'principle' which describes why bodies float.



Archimedes

Isaac Newton

The Romans contributed little to science, and very few new ideas emerged until Leonardo da Vinci began his experiments. He made some very valuable observations about nature, but he disliked deducing general laws to explain these observations. At the end of the 16th century and the beginning of the 17th Galileo Galilei in Italy, William Gilbert in London, and Stevinus in Holland were thinking, observing, and experimenting, using the same methods of research as are used today. By the turn of the century the foundation of modern physics had been laid down.

In the year that Galileo died Isaac Newton was born. He is best known for his experiments with light, and for his discovery of the laws of gravity. This was a tremendous step forward, because it related the fall of a stone to the motion of the planets around the sun. When Newton died in 1727 his greatness inspired many men to study physics. Faraday (1791–1867) investigated electricity and magnetism; Joule (1818–1889) discovered the true nature of heat as a form of energy; Maxwell (1831–1879) solved the problem of the nature of light. After this discoveries in physics followed in rapid succession, and were applied to such things as steam engines, the electricity generator, the electric motor, photography, and wireless communication.

At the end of the 19th century and the beginning of the 20th, new discoveries were made of even greater importance than those of Galileo and Newton. Physicists began to realise that the atom was not indestructible as they had previously thought. In fact it could be changed and even split. At the same time Albert Einstein was making important discoveries about the nature of space, time, energy, and light. His conclusions are extremely important whether physicists are examining the structure of the atom or the structure of the Universe.

We now know a great deal more than Archimedes about the workings of nature, but any physicist will tell you that there is still a great number of physical laws waiting to be discovered. Nature undoubtedly has many more surprises in store for us.